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TECHNICAL MEMORANDUM

TO:	Walt Hunt, Crown Resources	**DATE:**	October 16, 2003
FROM:	Scott Miller; David Landrault; Brent Bronson, and Jim Johnson, Golder Associates	**OUR REF:**	023-2002
RE:	**ALTERNATIVE COMPARISON UNDERGROUND PASTE BACKFILL WITH OFFSITE SURFACE DISPOSAL OF TAILINGS – BUCKHORN MT. PROJECT**		

1.0 Introduction

This memorandum provides a comparative review of the current proposed tailings management and mine backfill plan for the Buckhorn Mt. Project (Plan of Operations, Crown Resources July 31, 2003) with the use of paste tailings for underground disposal.

Paste tailings are defined as a dense, viscous mixture of tailings and water which, unlike slurries, do not segregate during mixing, transport and disposal. Paste tailings have a consistency very similar to wet concrete and when mixed with cement, can provide a high-strength underground mine backfill. A brief review of the potential advantages and disadvantages of underground paste tailings disposal in general and specifically at Buckhorn Mt. are summarized below as part of this Introduction. A comparative analysis of the alternative of underground paste tailings disposal is further evaluated in the following sections to consider the following criteria:

- Technical feasibility
- Potential environmental impacts and monitoring
- Legal framework
- Cost

1.1 Summary of Proposed Tailings Management

As discussed in the Plan of Operations, tailings are proposed to be transported from the mill and deposited in an engineered disposal facility, as a thickened tailings slurry with a solids content of approximately 50 percent. The proposed tailings management is comprised of the following elements:

- Ore will be transported to the mill from the mine site, approximately 6.5 miles by highway trucks on County and Forest Service roads The mill site and tailings disposal facility (TDF) will be located at the Dry Gulch site near Chesaw on private land controlled by Crown Resources.

- Tailings will be discharged from rotating points into the TDF as thickened tailings to promote consolidation and dewatering. Tailings will be treated using a cyanide destruct circuit prior to discharge to the TDF.
- The TDF will be comprised of an embankment, composite liner system with internal drainage and seepage collection and recovery. Seepage from the internal drain system (overdrain) will be reclaimed for re-use in the process. Additionally, a leak detection and recovery system will underlie the liner system.
- The TDF will include a tailing pond water reclaim system by either gravity flow or by floating barge. Water segregated from the tailings will be recycled to the mill.
- The TDF will be reclaimed by placing a vegetated cover over the consolidated tailings and creation of surface water channels to route runoff to an engineered spillway.
- To provide the needed structural backfill for the mine the TDF site will also serve as a borrow location for underground mine backfill. The borrow materials will consist of glacial gravels, sands and silts.

The proposed TDF was selected because it has suitable construction and backfill materials, is not located on wetlands, minimizes disturbance on public lands, combines the TDF site construction requirements with the excavation of the needed borrow materials, is a proven technology with redundant environmental protection systems, and is consistent with Washington State regulations for tailings management.

1.2 Advantages of Underground Disposal of Paste Tailings

Underground paste tailings disposal has been evaluated because of a number of potential benefits including:

Typical (Generic) Advantages of Paste Tailings

- Underground disposal of paste tailings reduces the volume and area required for the surface tailings disposal
- The use of paste tailings reduces the quantity of fresh water required for makeup and the overall flow through of water within the process circuit inventory.
- Paste tailings is a proven technology for structural backfill. Underground disposal of tailings provides a source of structural backfill material eliminating the need for a borrow area for backfill materials, surface stockpiles, and the associated haul of borrow to the mine site.
- In comparison to normal tailings slurry, laboratory studies indicate that paste tailings may reduce the potential for acid generation and leaching from tailings due to the low permeability of paste tailings which minimizes oxidation and migration of contaminants.

Potential Advantages of Paste Tailings Specific to the Buckhorn Mountain Project

- The placement of paste tailings could eliminate the need to haul ore from the mine to the Dry Gulch site, if a suitable surface tailings disposal facility could be sited and constructed near the mine site.
- Underground disposal of tailings would provide a source of structural backfill material thereby eliminating the need for a borrow area for backfill materials, surface stockpiles, and the associated haul of borrow to the mine site.

1.3 Disadvantages of Underground Paste Tailings Disposal

While there may be potential advantages associated with the underground paste tailings disposal at the Buckhorn Mt. Project, there are also a number of potential disadvantages including:

Typical (Generic) Disadvantages Associated with Paste Tailings

- Underground paste tailings disposal typically can only accommodate a maximum of 60 percent of the material mined due to the volume increase of tailings over in-place rock, therefore as with every mine, a surface impoundment for tailings storage will be required. Consequently, it is generally not possible to completely eliminate the surface disposal of tailings by completely backfilling the mine.
- Underground paste tailings disposal does not provide engineered containment of the tailings. The paste tailings is in direct contact with the environment (i.e., the groundwater system.).
- The long-term environmental performance of underground paste tailings has not been demonstrated. Remediation of potential groundwater impacts would be difficult and costly, if it were to occur.
- Capital and operating costs are comparable for paste tailings to normal tailings slurry surface conveyance and placement.
- A smaller surface impoundment typically has a higher capital cost per unit mass, and the effectiveness of the proposed sub-aerial disposal to promote consolidation may be reduced due a smaller impoundment size.

Potential Disadvantages of Paste Tailings Specific to the Buckhorn Mountain Project

- Underground paste tailings disposal would require that the mill be located at the mine site which would increase the disturbance area on public lands and would require increased infrastructure (power and water) at the mine. Also, the distance to transport processing materials and reagents to the mill site on Buckhorn Mountain would be increased.
- The fine-grained nature of the Buckhorn Mt. tailings requires substantially more cement additive for stability to achieve the design strength requirements in comparison to gravel backfill.
- Underground disposal of paste tailings is not consistent with the Revised Code of Washington RCW 78.56.100 that requires an engineered liner system with leak

detection and collection systems for tailings disposal. In other words, Washington regulations require engineered containment of tailings.

2.0 Technical Feasibility

Tailing paste has been used extensively as an underground structural fill in the Sudbury district and elsewhere in Canada, and a zinc mine in Sweden.

The use of paste tailings for underground backfill has been developed to reduce process water consumption and to reduce the need for development of surface backfill quarries and the cost for placement of backfill. Underground disposal of paste tailings for structural fill is very cost effective in deep mine applications such as Falconbridge's Kidd Creek Mine in Timmins, Ontario. This mine is over 6,000 feet deep and conveyance of rock fill is prohibitively expensive. Paste is pumpable or transportable by a gravity pipeline and therefore is easy to move and eliminates the need for a surface quarry. Additionally, there are at least 12 other mines in Canada using paste tailings backfill including Bouchard-Hebert, Lupin, Louvicort, Doyon, Gonzeque-Langlois, Campbell, Red Lake, Garson, Laronde, Golden Giant, Williams, and Metagami. A number of these mines employ cyanide in their process without reported environmental issues. Long-term environmental monitoring performance data for the paste backfill at the Canadian mines is not available, as these mines are still actively being dewatered and operated. Mine dewatering at these sites currently prevents groundwater from coming into contact with the paste tailings backfill, and migrating to the environment after interacting with the paste backfill.

In the US, the Stillwater Mine in Montana and Greens Creek Mine in Alaska are both using paste tailings as underground backfill. Neither of these US mines utilize cyanide for ore processing.

The current mine backfill plans call for approximately 700,000 cubic yards (yds^3) of cemented structural backfill and 900,000 yds^3 of uncemented backfill using the glacial materials excavated from the TDF footprint and the development rock from the mine. Development rock from the mine will account for approximately 300,000 to 400,000 yds^3 of the uncemented backfill. Paste tailings could be developed with a similar strength to a cemented glacial material backfill. The design criteria for the compressive strength of the cemented structural backfill at the Buckhorn Mt. Mine is up to approximately 1,000 pounds per square inch (psi), depending on the area of placement. The glacial-derived borrow material from the footprint of the proposed TDF will require approximately 5 percent cement additive to achieve this rock strength. With the design strength requirement and fine grind of the tailings, a cement addition of approximately 7 percent is estimated to achieve the same strengths of the glacial materials backfill with a 5 percent cement addition.

Another notable difference between paste tailings and glacial material backfill is that paste must have at least 2 percent cement addition to prevent liquefaction during operations, whereas the glacial borrow and development rock backfill can be used in non-critical fills without cement addition. The Buckhorn Mt. Mine will have 900,000 yds^3 of uncemented backfill that would require a 2 percent cement addition if this volume were replaced with paste backfill.

Underground disposal of paste tailings requires the mill and paste plant to be located at or near the mine. Typically, in a backfill application the maximum amount of tailings that can be placed underground is 60 percent of the mined volume due to swell and the inability to fill all the voids. This would require a surface disposal facility for the remaining tailings volume. In the case of Buckhorn Mt. this would require that a surface impoundment be constructed for approximately 1.6 million tons (Mt) of tailings. Options for the surface disposal of tailings include using the

proposed TDF site at Dry Gulch or finding an alternative site near the mine. Each of these options are technically feasible but have challenges including:

- Smaller (reduced footprint) TDF at Dry Gulch Site: The smaller impoundment would have a smaller embankment but would still require the majority of lined area and associated area of disturbance and infrastructure. With the mill located at the mine site, a pipeline for conveyance of the slurry tailings would be required to connect to the TDF.
- Smaller (reduced footprint) TDF at Mine Site: A TDF could be located near the mine at any of the sites developed by Battle Mt. Gold in their tailings sitings studies for the Crown Jewel Project. This facility would be located on public lands and would result in wetland losses and, in most cases, extensive forest clearing.

In summary, using paste tailings as underground mine backfill is technically feasible but surface storage will, nevertheless, be necessary. However, as discussed in the following section, there are environmental issues associated with paste tailings.

3.0 Environmental Impact and Monitoring

The following is a summary of the potential environmental implications for the use of paste tailings as underground backfill.

- A TDF would be required for approximately 1.6 Mt of tailings. A smaller surface TDF reduces many of the cost and scale efficiencies for area of liner and embankment volume versus tailings volume.
- Based on laboratory studies, the theoretical environmental performance of cemented paste tailings backfill is expected to be good due to its low permeability. However, there are no full-scale examples for comparable settings with adequate historical monitoring that can be used to confirm the laboratory studies. Any leachate from the paste tailings would not be contained and would be released to the environment. Additionally, any impacts related to underground paste tailings disposal could not be readily monitored under controlled conditions and may not be manifest for decades. Mitigation or correction of impacts would be significantly more complicated due to location and lack of containment. In contrast, the proposed TDF at Dry Gulch will have a composite liner which provides for containment of the tailings and internal drainage, leak collection and water management control systems, all of which allow direct monitoring of the environmental performance.
- Paste tailings would require that the mill and paste plant be located at the mine site. Powerlines, water pipelines and reagents hauling and storage would all be required at the mine site which would increase the area of disturbance on public lands. In particular the corridor for a required high tension power line would add substantially to the area of disturbance in comparison to the proposed lower voltage power line along the access route between Dry Gulch and the mine site.

The areas of disturbance for the proposed mine, mill and TDF sites for the proposed TDF is compared below with the estimated disturbance associated with a paste tailings backfill alternative.

Facility	Estimated Area of Disturbance for the Proposed TDF Alternative	Estimated Area of Disturbance for the Paste Tailing Backfill Alternative*
Mine Site	20 acres	40 acres (now includes mine and mill)
Remote Mill Facilities Site (including water storage and backfill stockpile)	38 acres	10 acres (water storage pond only)
TDF, Borrow Area, and Reclaim	52 acres	40 acres (does not include temporary disturbance related to the tailings pipeline)
Other	23 acres	23 acres
Power Line Corridor, Chesaw – Mine Site	---**	35 acres
Totals	**133 acres**	**148 acres**

* Acreages for paste alternative are estimates only
** Not required

Paste tailings have been utilized in a number of underground mine backfills. The focus on these backfill applications has been on the economic considerations of geotechnical performance (i.e., for structural backfill), reduced water consumption, reduced volumes of tailings on the surface, and lower cost of placement versus rock fill in deeper mines. The primary environmental benefit considered for underground paste disposal in many applications is the isolation and buffering of acid generating tailings that in some jurisdictions would normally be deposited in an unlined or clay lined surface facility in contact with the atmosphere. However, as further discussed in the following section, a concern with underground paste disposal technology at Buckhorn Mtn. is the Washington state regulations prohibit disposal of tailings in an unlined or clay-lined facility.

The environmental performance and monitoring of sites using cyanidated paste tailings for underground backfill is not well documented. Laboratory leachability and humidity cell tests indicate that paste tailings are relatively impermeable and provide a hydraulic barrier to the leaching and movement of contaminants from the tailings even when the material is potentially acid generating (see attached paper by Verburg et al.). However, the performance of cyanide bearing backfill has not been evaluated in any long-term, full scale setting. There are several gold mines in Canada where tailings paste backfill containing cyanide has been used without any reported impacts, but again, the mine is dewatered preventing migration of groundwater into and out of the backfilled mine. The location of this mine in permafrost also differs from the setting of the Buckhorn Mt. Mine. As discussed above there are no operations in the US that place detoxified cyanidated tailings underground as paste. Consequently, while very promising, the environmental performance of underground disposal of cyanidated paste tailings has not been documented.

The environmental performance of a lined surface tailings disposal facility is well documented as an effective and proven technology. In addition, if any environmental issues develop during operation or after reclamation, seepage can be collected for water treatment or passive management in some other fashion like evaporation in lined containment. Remediation under such circumstances would be

accomplished within a limited time frame. In an underground mine the monitoring and mitigation of any potential problems is difficult.

Underground paste tailings disposal performance is well documented for geotechnical applications but there is no longer term, well documented environmental performance information to support a preference for this technology from an environmental standpoint at Buckhorn Mt.

4.0 Legal Framework

The design and permitting of tailings disposal facilities in the State of Washington is regulated by Chapter 78.56 Metals Mining and Milling Operations RCW. Of particular concern for the use of paste tailings as underground backfill are State laws pertaining to tailings disposal as presented in Ch. 78.56.0100 and excerpted below:

> *(ii) The tailings facility shall have a containment system that includes an engineered liner system, leak detection and leak collection elements, and a seepage collection impoundment to assure that a leak of any regulated substance under chapter 90.48 RCW will be detected before escaping from the containment system. The design and management of the facility must ensure that any leaks from the tailings facility are detected in a manner which allows for remediation pursuant to chapter 90.48 RCW. The applicant shall prepare a detailed engineering report setting forth the facility design and construction. The applicant shall submit the report to the department of ecology for its review and approval of a design as determined by the department. Natural conditions, such as depth to ground water or net rainfall, shall be taken into account in the facility design, but not in lieu of the protection required by the engineered liner system;*
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> *(iii) The toxicity of mine or mill tailings and the potential for long-term release of regulated substances from mine or mill tailings shall be reduced to the greatest extent practicable through stabilization, removal, or reuse of the substances; and*
>
> *(iv) The closure of the tailings facility shall provide for isolation or containment of potentially toxic materials and shall be designed to prevent future release of regulated substances contained in the impoundment;*

The use of tailings as underground backfill does not comply with Washington's regulations which specifically require that tailings disposal include engineered lined containment with leak detection and collection systems. Underground disposal of tailings is not consistent with the law requiring engineered containment with leak detection and collection. Therefore, it is noted that, with the current legal framework, paste tailings disposal is not a viable alternative to the proposed tailings management strategy.

5.0 Cost

The paste tailings cost considerations would include:

- Paste plant is estimated at a capital cost of $3 million. In addition, the underground distribution system capital costs would be on the order of $1.3 million.

- The cost per unit volume of surface tailings disposal typically increases as the economy of scale is reduced. All the same infrastructure and monitoring is required for a smaller volume. Capital costs for the smaller surface TDF have not been developed but are expected to be in the range of $3 per ton or $4.8 million.
- Operating costs for the dewatering and placement are generally in the range of $3 to $6 per ton per ton of paste.
- Paste plant and mill location should be at the mine, thereby requiring water supply pipeline, powerline, and additional deliveries to the mine.
- Paste tailings would require a minimum of 7 percent cement in the structural fill, and 2 percent in the normal backfill. This represents an increased cement use over the rockfill.
- A slurry pipeline would be required between the mill located at the mine and a tailings disposal site at Dry Gulch or a location on Buckhorn Mt.

Detailed cost estimates for the proposed TDF at Dry Gulch are in preparation, however the capital cost for the facility are anticipated to be in the range of $8 million dollars with an operating cost of $1 per ton. Trucking costs for ore from the mine to the Dry Gulch TDF site are estimated at $1.32/ton.

Closure costs have not been estimated for either alternative but would be expected to be less for the paste tailings option due to the smaller surface TDF. However, if the smaller TDF is located on Buckhorn Mt. the closure costs and engineering will likely be higher due to stormwater issues not present at the Dry Gulch site.

Long-term monitoring costs of the paste alternative is anticipated to be much higher and the potential for long-term mitigation, however remote, could be very high.

A very preliminary cost comparison is presented in the following table:

Cost Item	Proposed Dry Gulch TDF	Underground Paste Backfill and On-Site TDF*
Capital Cost	$8 M	$9.1 M**
Tailings Disposal Operating Cost per Ton	$1	$3.10
Backfill Costs per Ton	$1.95	Included
Cement Cost per Ton	$1.10	$2.30
Ore Transport Cost per Ton	$1.32	Included
Operating Cost Per Ton	$5.37	$5.40

* All estimates are based on conceptual design information and are for comparative purposes only.
** Excludes higher power line capital

Based on this very preliminary cost analysis, capital and operating costs for the proposed Dry Gulch TDF are expected to be comparable to the combined paste tailings and smaller Dry Gulch TDF. These costs do not take into account the higher production rates and quicker stope turnaround achievable with paste backfill, nor do they include closure costs which depend on the site selected as

discussed above. Economies of scale in a small operation such as Buckhorn Mt. are not fully realized in either the capital or operating cost.

6.0 Summary and Conclusions

Based on the authors' understanding of the highly protective regulatory environment in Washington State and Crown Resources' stated desire to utilize effective and proven approaches to environmental protection, it is recommended that the alternative of paste tailings for underground structural backfill, while technically feasible, should not be advanced as the preferred option. The reasons for this recommendation are as follows:

1) The use of paste tailings for backfill will not eliminate the need for a separate surface tailings impoundment. The use of the proposed remote Dry Gulch location as a scaled down site for a TDF would result in operational and environmental complications. The suitability of alternate sites nearby on Buckhorn Mt. is environmentally less desirable and incrementally enlarges surface disturbance on public land.

2) The long-term environmental performance of paste tailings as underground backfill has not been demonstrated.

3) In contrast, the proposed surface TDF incorporates proven and redundant environmental protection, as required by Washington's regulations, and the location will provide a borrow source of backfill material within its footprint of disturbance.

4) In relation to underground tailings disposal the proposed TDF provides for on-going operational monitoring and remediation options. Additionally, reclamation of the Dry Gulch site is far superior in cost, effectiveness and practicality to any potential surface disposal sites in the steeper terrain of the Buckhorn Mt. area.

5) While the infrastructure requirements associated with the paste backfill option have not been studied in detail, no reduction in area of disturbance would be realized in comparison with the proposed action. Given the steep terrain in the area of the mine, site-specific engineering may well reveal significant increases in disturbance area over the estimates provided.

6) Surface disturbance associated the paste option will be increased on public lands regardless of the TDF location and will almost certainly result in detrimental effects to forest and wetland habitat in comparison to the proposed alternative.

7) Underground disposal of tailings is not permitted under the laws of the State of Washington.